



National Aeronautics and
Space Administration

Washington, D.C.
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Reply to Attn of: SL

TO: A/Administrator
FROM: S/Associate Administrator for Space Science and Applications
SUBJECT: Ulysses Launch

The Ulysses Mission will send a sophisticated spacecraft in a high inclination orbit toward the Sun's south pole reaching previously uncharted heliographic latitudes. The mission goal is to provide an accurate assessment of our total solar environment. Ulysses will provide the first *in situ* three dimensional observation of the inner heliosphere. On its journey to the Sun, Ulysses will measure field and particles. About five years after launch, Ulysses will have explored the heliosphere at nearly all latitudes, measured phenomena over both of the Sun's poles and investigated interplanetary particles and fields. Ulysses is a joint mission between the United States National Aeronautics and Space Administration and the European Space Agency.

The Ulysses spacecraft will be launched in October, 1990, by the Shuttle and Payload Assist Module/Inertial Upper Stage on an ecliptic transfer orbit to Jupiter. Upon arrival at Jupiter, approximately sixteen months after launch, Ulysses will measure the Jovian magnetosphere. Ulysses will then use the massive Jovian gravitational field to deflect the spacecraft trajectory out of the ecliptic.

Ulysses, on a five year mission, with its array of nine sophisticated instruments will measure the properties of the solar corona, the solar wind, the Sun/wind interface, the heliospheric magnetic field, solar radio bursts, plasma waves, solar X-rays, solar and galactic cosmic rays and interstellar neutral gas and dust. In addition the Ulysses mission will afford scientists the opportunity to take advantage of the enormous distance between the spacecraft and the Earth to perform astrophysical measurements, and to search for gravitational waves. In conjunction with instrumentation on Earth-orbiting spacecraft, Ulysses will help to precisely locate the mysterious sources of cosmic gamma bursts.

The results from the mission will help solve outstanding problems in solar and heliospheric physics, while undoubtedly revealing new and unanticipated phenomena. It should be remembered that the most exciting results from exploratory missions are frequently unanticipated. NASA and the nation can look forward with pride and anticipation to the results from this mission.

L. A. Fisk
Enclosure

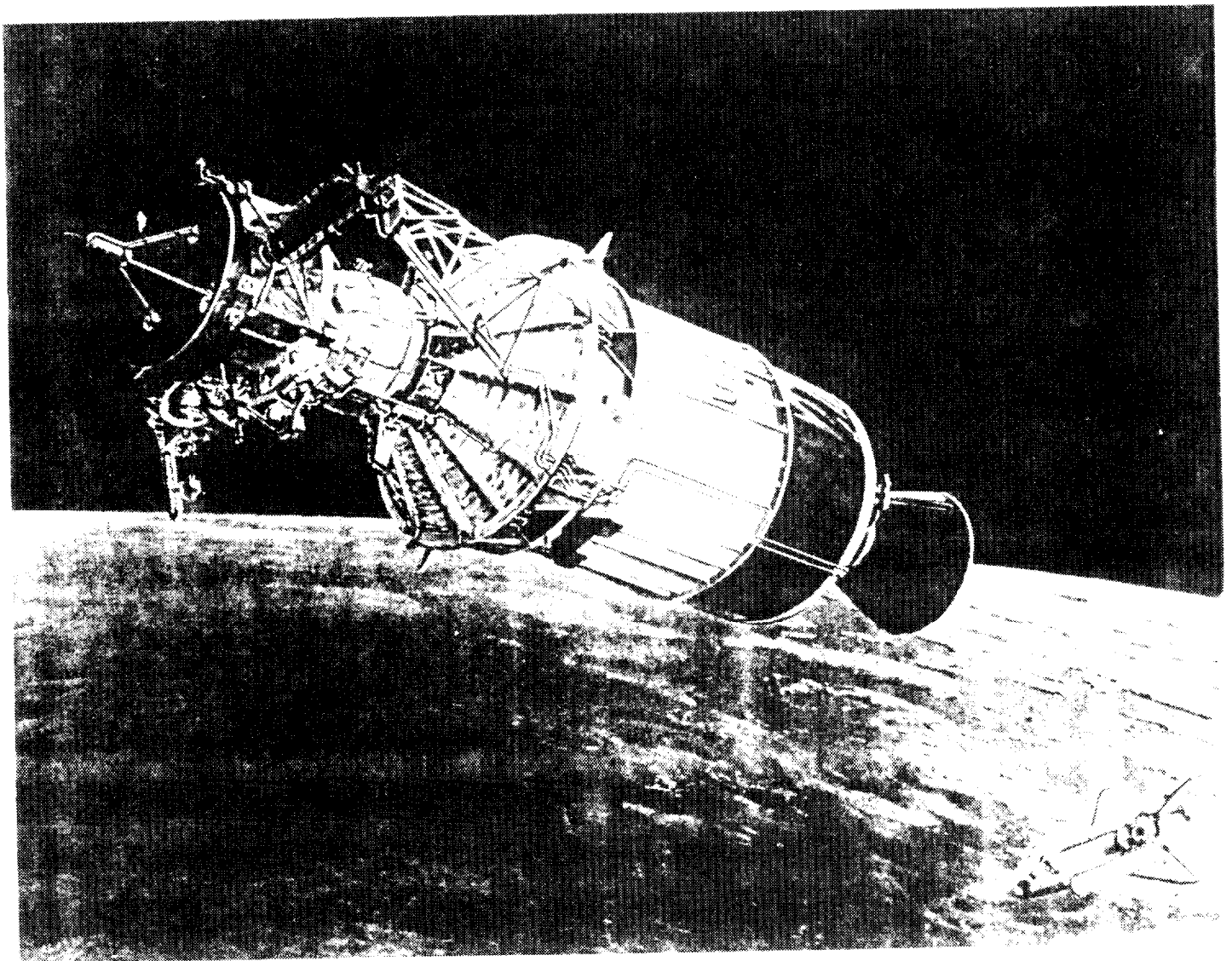


National Aeronautics and
Space Administration

Mission Operation Report

OFFICE OF SPACE SCIENCE AND APPLICATIONS

Report No. S-448-41-90-01



ULYSSES

FOREWORD

Mission Operation Reports are published expressly for the use of NASA senior management, as required by NASA Management Instruction NMI 8610.3D, dated May 13, 1982. The purpose of these reports is to provide NASA senior management with timely, complete, and definitive information on flight mission plans, and to establish official mission objectives that provide the basis for assessment of mission accomplishment.

Reports are prepared and issued for each flight project just prior to launch. Following launch, report updates for each mission are issued to keep management informed of definitive mission results, as required by NASA Management Instruction HQMI 8610.1B.

These reports are sometimes highly technical and are for personnel having program/project management responsibilities. The Public Affairs Division publishes a comprehensive series of reports on NASA flight missions, which are available for dissemination to the news media.

Prepared by
SOLAR SYSTEM EXPLORATION DIVISION
NASA HEADQUARTERS

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OVERVIEW

Ulysses is a joint mission between the United States National Aeronautics and Space Administration (NASA) and the European Space Agency (ESA) to explore the heliosphere over the full range of solar latitudes, especially in the polar regions. The goal of the Ulysses mission is to provide an accurate assessment of our total solar environment. This collaborative ESA/NASA mission will, for the first time, explore the heliosphere -- the region of space that is dominated by the Sun (Figure 1) -- within a few astronomical units of the Sun over the full range of heliographic latitudes. The path followed by the spacecraft, using a Jupiter gravity-assist to achieve a trajectory extending to high solar latitudes, will enable the highly sophisticated scientific instruments on board to make measurements in the uncharted third dimension of the heliosphere. The Ulysses spacecraft will carry nine scientific instruments to measure the properties of the solar corona, the solar wind, the Sun/wind interface, the heliospheric magnetic field, solar radio bursts, plasma waves, solar X-rays, solar and galactic cosmic rays, and the interplanetary/interstellar neutral gas and dust. Scientists will take advantage of the enormous distance between the spacecraft and the Earth to perform astrophysical measurements and to search for gravitational waves. In conjunction with instrumentation on Earth-orbiting spacecraft, Ulysses will help to precisely locate the mysterious sources of cosmic gamma bursts. The results obtained will help to solve outstanding problems in solar and heliospheric physics, while undoubtedly revealing new and unanticipated phenomena.

Background

The basis for the Ulysses project was first conceived in the late 1950's by Prof. J.A. Simpson of the University of Chicago. Originally it was planned as a two-spacecraft mission between NASA and ESA. Named "Out of Ecliptic," this mission would enable scientists to study regions of the Sun and the surrounding space environment above the plane of the ecliptic that had never before been studied. Later the project name was changed to "International Solar Polar Mission" (ISPM). Unfortunately, delays in Shuttle development and concerns over the effectiveness of the Inertial Upper Stage (IUS) led to a House Appropriations Committee recommendation in the 1980 Supplemental Appropriations Bill that ISPM be terminated. Later, in 1981, budget cuts led NASA to cancel the U.S. spacecraft contribution to the joint NASA/ESA ISPM mission. The ESA spacecraft completed its flight acceptance tests in early 1983 and was placed in storage.

In 1984, the ISPM mission was renamed as the "Ulysses Project," following a proposal by Prof. Bruno Bertotti, of the University of Pavia, Italy. It was to be launched in 1986. After the Challenger incident, it was again rescheduled, this time for a 1990 launch. An overview of the history of Ulysses is represented in Table 1.

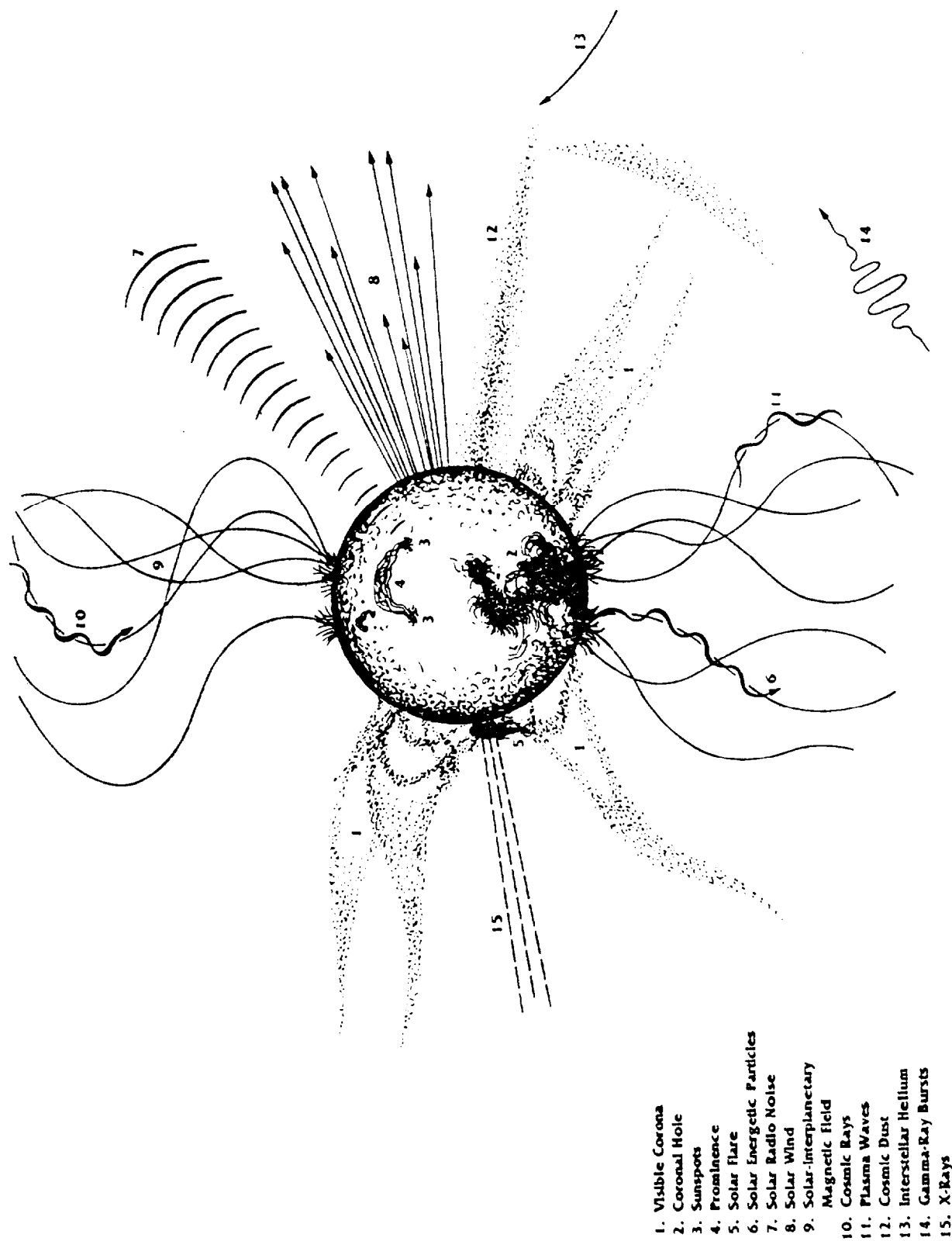


Figure 1. Solar Influence

TABLE 1. ULYSSES HISTORICAL SUMMARY

	Spacecraft		Launch Vehicle/Upper Stage	Launch Date
October 1978 Project Start	1 NASA S/C	1 ESA S/C	Single STS/IUS (3-stage launch)	1983 launch
April 1980			Split launches 1 NASA, 1 ESA	Launch deferred to 1985
February 1981	NASA SC "slowdown"		Launch vehicle changed to STS/Centaur	Launch deferred to 1986
September 1981	U.S. S/C cancelled			
January 1982			Launch vehicle changed to STS/IUS (2-stage)	
July 1982			Launch vehicle changed to STS/Centaur	
January 1986			Challenger accident	Launch deferred indefinitely
June 1986			STS/Centaur program cancelled	
November 1986			IUS/PAM-S upper stage procurement decision	
April 1987				Launch date selected-- October 1990

Mission Rationale

The study of interactions at the Sun's poles among solar wind, solar magnetic fields, and cosmic rays are of fundamental interest to space physicists. High solar latitude observations of the photosphere and the corona, regions of the Sun that give rise to most of the physical phenomena that fill the heliosphere, will greatly aid solar physicists in the development of a complete and coherent model of the Sun and its heliosphere.

Despite the general acceptance that the heliosphere is intrinsically three-dimensional in nature, our current understanding of the physical processes occurring within this environment is essentially based on observations made close to the plane of the ecliptic. Most interplanetary spacecraft have remained within a small angle of the ecliptic plane; consequently, our view of the Sun and our solar system's interplanetary environment has been very restricted. Our present understanding of the Sun could be compared to trying

to make a map of the Earth by flying an airplane around the equator. Ulysses, having as its primary objective the study of the inner heliosphere in three dimensions, will provide the first *in situ* observations covering the full range of heliographic latitudes.

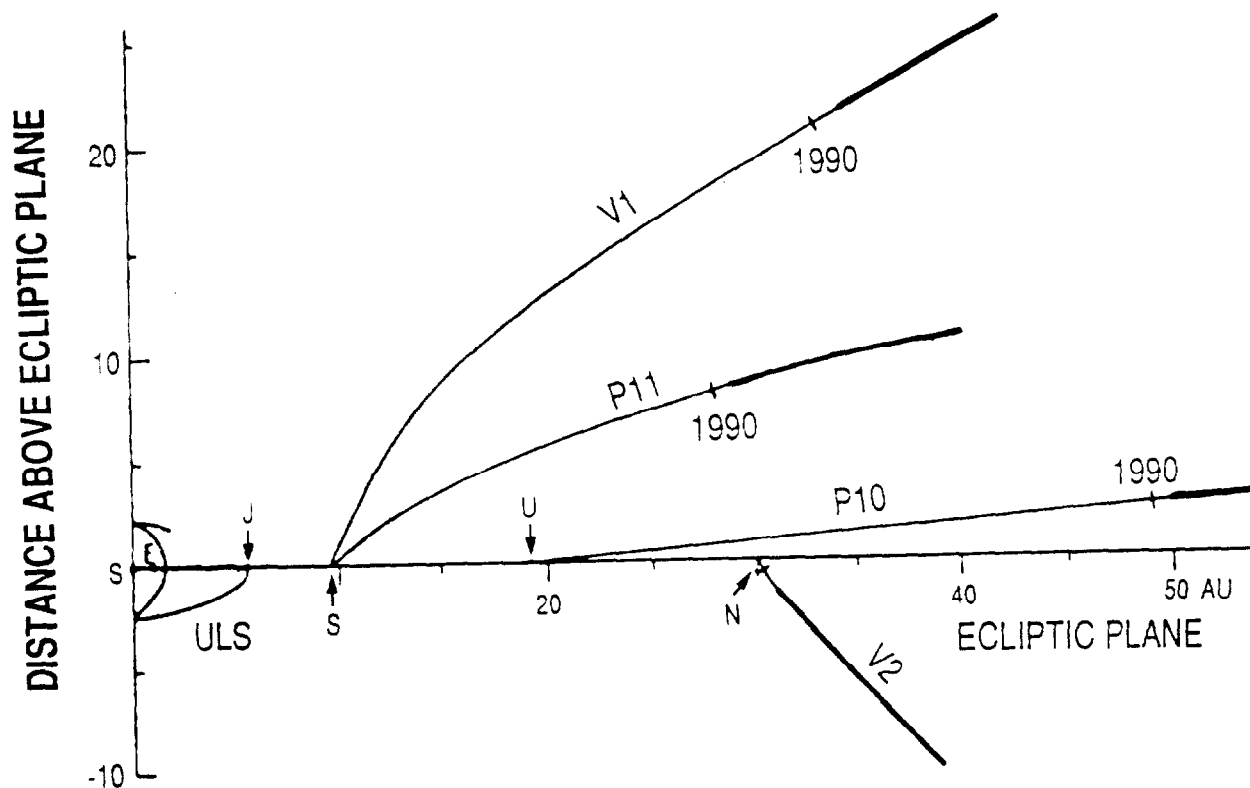
Benefits to be Derived

Ulysses is expected to make major scientific contributions to the International Heliospheric Study. The aim of this study is to provide coordinated investigations of the large-scale structure of the heliosphere by exploiting the simultaneous existence of four spacecraft in the outer heliosphere (Pioneer 10, 11 and Voyager 1, 2), Ulysses in the inner heliosphere, and other spacecraft in the ecliptic. The relationship of the Ulysses trajectory to the network of the deep-space missions, all of which will be beyond 30 AU in the first half of the 1990's, is shown schematically in Figure 2.

Most scientists agree that the solar wind that flows from the Sun's poles probably has constant speed, unlike the wind from the equator. Such straightforward streams of particles are not expected to tangle the magnetic field lines above the poles. The magnetic field lines there may be more open and less complicated than the twisted and tangled paths near the equator. If that is true, scientists could measure and understand many events that cannot be understood near the equator. The major accomplishment would be a clarification of conflicting theories about the heliosphere. For example, cosmic rays that enter the solar system near the Sun's equator are robbed of their energy as they twist and turn and leap along the complex magnetic field lines. They are altered so dramatically by the loss of energy as to be almost unrecognizable. Galactic cosmic rays must be detected in their original, pristine condition if their true nature is to be understood. Scientists believe that cosmic rays in or near this condition can be detected over the Sun's poles. Ulysses will attempt to detect these particles in their unaltered state.

Ulysses will make observations during the maximum and the declining phases of the solar cycle. The pole-to-pole passage will occur near solar minimum conditions, and the spacecraft should encounter a relatively well-ordered heliospheric structure in which latitude dependencies are most obvious.

In addition, Ulysses will allow scientists to study the behavior of interstellar neutral and ionized gas in the heliosphere and the heliopause where effects of the solar wind are at a minimum. And, for the first time, the measurement of the speed and flight direction of particles within the interplanetary dust cloud will be made well above the ecliptic.



Spacecraft trajectories mapped into a common meridian plane. Distances from the Sun (S) are in astronomical units (AU). The trajectory segments covered after October 1990 are drawn by heavy lines. ULS = Ulysses, V = Voyager, P = Pioneer, E = Earth, J = Jupiter, S = Saturn, U = Uranus, N = Neptune.

Figure 2. Spacecraft Trajectories

Prior Mission Results

Astrophysicists study the Sun because it is the only star that is close enough to study in detail. Physicists probe the Sun because it is a marvelous laboratory where they can observe unique conditions of temperature, density, fluid motions, and magnetic fields. The goal of atmospheric physicists and climatologists is to understand the Sun's effects on the Earth. These scientists can trace the lineage of their endeavors back more than three centuries to the year 1610 when Galileo aimed his new telescope at the Sun and saw for the first time that our nearest star rotates and that its surface is speckled with sunspots.

While our knowledge has grown a thousandfold since Galileo's time, it was the advent of space exploration in 1958 that accelerated our understanding of the Sun. Suddenly scientists could send their instruments above Earth's atmosphere, which clouds and distorts their viewing.

For more than two and one-half decades scientists have mounted instruments on spacecraft to study the Sun and the solar wind -- and the entire heliosphere. Mariner 2, for example, confirmed the existence of solar wind, a plasma that streams from the Sun. But none of these machines could fly above the plane of the ecliptic -- the plane in which Earth orbits the Sun. To fly out of the ecliptic, to overcome the energy imparted to a spacecraft by the motion of Earth around the Sun, requires more rocket power than is available. Therefore scientists have been unable to study two subjects of great importance: the entire set of interactions of solar wind, magnetic fields, and cosmic rays that take place at the Sun's poles; and interactions of the three-dimensional physics of the Sun.

MISSION OBJECTIVES

Primary Objectives

The primary objectives of the Ulysses mission are to investigate for the first time, as a function of solar latitude, the properties of the solar wind, the structure of the Sun/wind interface, the heliospheric magnetic field, solar radio bursts and plasma waves, solar X-rays, solar and galactic cosmic rays, and interstellar interplanetary neutral gas and dust.

Secondary Objectives


Secondary objectives of the mission include interplanetary-physics investigations during the in-ecliptic Earth-Jupiter phase, measurements of the Jovian magnetosphere during the Jupiter flyby phase, the detection of cosmic gamma-ray bursts, and a search for gravitational waves from cataclysmic cosmic events.

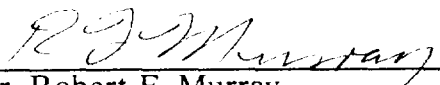
Science Objectives

The detailed scientific objectives of the various instruments, as they contribute to the overall Ulysses objectives, are as follows:

- To provide an accurate assessment of the global three-dimensional properties of the interplanetary magnetic field and the solar wind
- To improve our knowledge of the composition of the solar atmosphere and the origin and acceleration of the solar wind by systematically studying the composition of the solar-wind plasma and solar energetic particles at different heliographic latitudes
- To provide new insight into the acceleration of energetic particles in solar flares and into storage and transport of these particles in the corona by observing the X-ray and particle emission from solar active regions and from other magnetic configurations that are more accessible for study from out-of-the ecliptic
- To further our knowledge of the internal dynamics of the solar wind, of the waves, shocks and other discontinuities, and of the heliospheric propagation and acceleration of energetic particles, by sampling plasma conditions that are expected to be different from those available for study near the ecliptic

- To improve our understanding of the spectra and composition of galactic cosmic rays in interstellar space by measuring the solar modulation of these particles as a function of heliographic latitude and by sampling these particles over the solar poles, where low-energy cosmic rays may have an easier access to the inner solar system than near the ecliptic plane
- To advance our knowledge of the neutral component of interstellar gas by measuring as a function of heliographic latitude the properties and distribution of neutral gas that enters the heliosphere
- To improve our understanding of interplanetary dust by measuring its properties and distribution as a function of heliographic latitude
- To search for gamma-ray-burst sources and, in conjunction with observations from other spacecraft, to identify them with known celestial objects or phenomena
- To search for low-frequency gravitational waves by recording very precise two-way Doppler tracking data at the ground stations.


 Dr. Wesley T. Huntress, Jr.
 Director
 Solar System Exploration Division


 Mr. Robert F. Murray
 Ulysses Program Manager

MISSION DESCRIPTION

Mission Plan

The Ulysses spacecraft will be launched from the Kennedy Space Center using the NASA Space Shuttle (Figure 3) for insertion into near-Earth orbit. An IUS/PAM-S upper stage combination will inject it into an interplanetary trajectory toward Jupiter (Figures 4 and 5). Ulysses will then use Jupiter as a gravity assist, passing near the north pole of the planet. At this point, the Jovian gravitational field will deflect the spacecraft into a high-inclination orbit, taking it south of the ecliptic plane. This high-inclination orbit will result in a maximum solar latitude of 72 to 85 degrees, an aphelion at 5.4 astronomical units (AU), and perihelion at 1.3 AU.

Launch will take place in early October 1990. A fly-by of Jupiter will occur in February 1992, while arrival at the southern solar latitudes is scheduled for May 1994. The spacecraft will arrive at the northern latitudes in May 1995 and will spend a minimum of 150 days above 70 degrees latitude.

The primary mission will come to an end almost five years after launch when the spacecraft dips below 70 degrees north latitude. The spacecraft will have detected and measured particles inbound from the Milky Way, explored the heliosphere at almost all latitudes, and measured phenomena above both poles of the Sun.

International Cooperation

The NASA and ESA responsibilities for the cooperative Ulysses mission were defined in a Memorandum of Understanding (MOU), agreed upon for the original dual-spacecraft mission, dated 29 March 1979. ESA is responsible for the development of the spacecraft and its in-orbit operation, as well as providing mission operations support personnel, operations software, and approximately one-half of the science instruments. NASA provides the remaining one-half of the science instruments and is responsible for provision of the launcher and all launch services, provision of the spacecraft's power generator, operating the Ulysses Mission Control Center, tracking and data-acquisition support by the Deep Space Network (DSN), and processing and distribution of the data. The scientific payload is made up of instruments from both the US and ESA member states. The mission is being carried out by two projects -- one American and one European -- located at JPL. Each project has its own Project Manager and Project Scientist. Joint decisions are made by a Joint Working Group (JWG), consisting of the two Project Managers and the two Project Scientists. This division of responsibilities is summarized in Table 2.

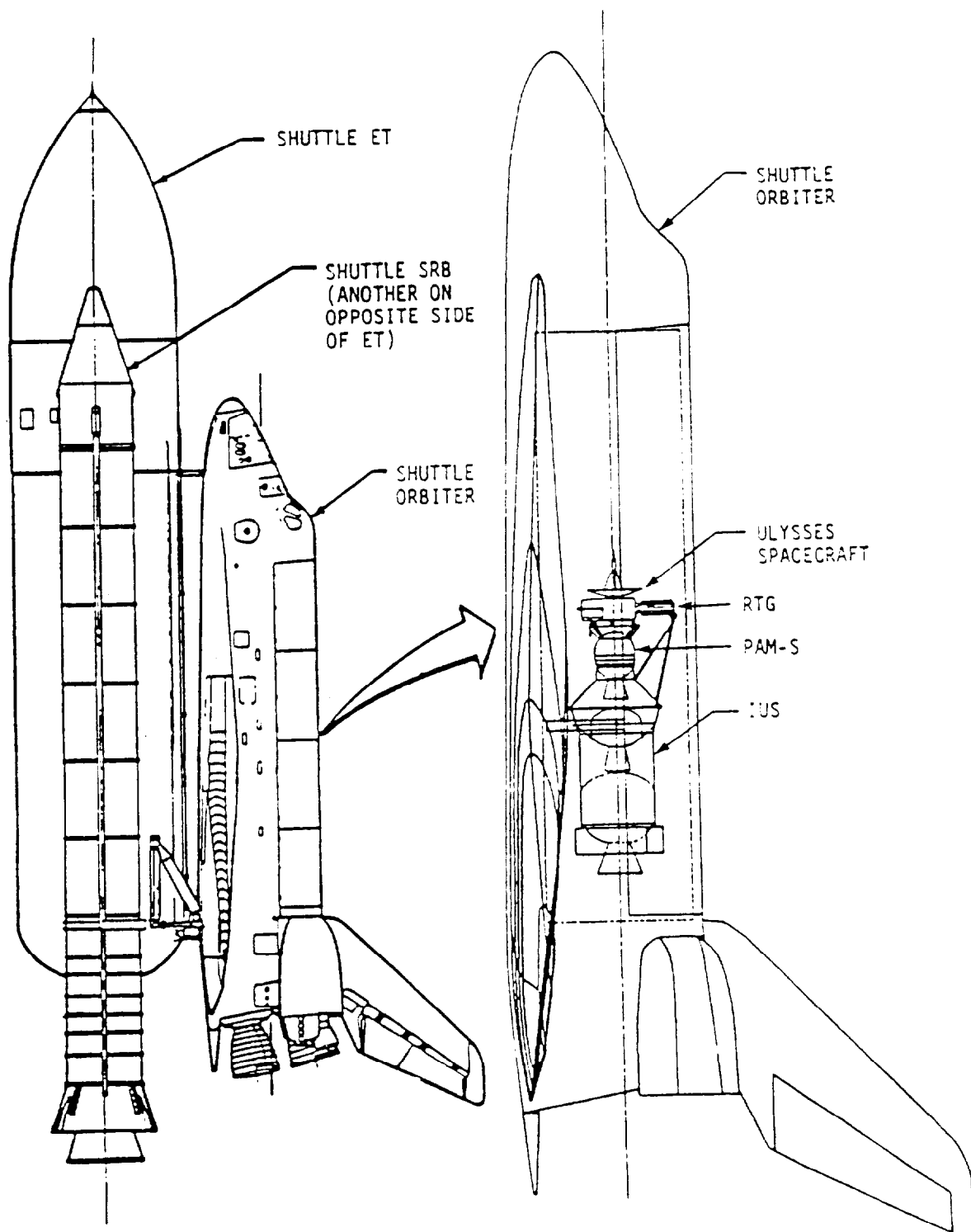


Figure 3. Ulysses Launch Configuration

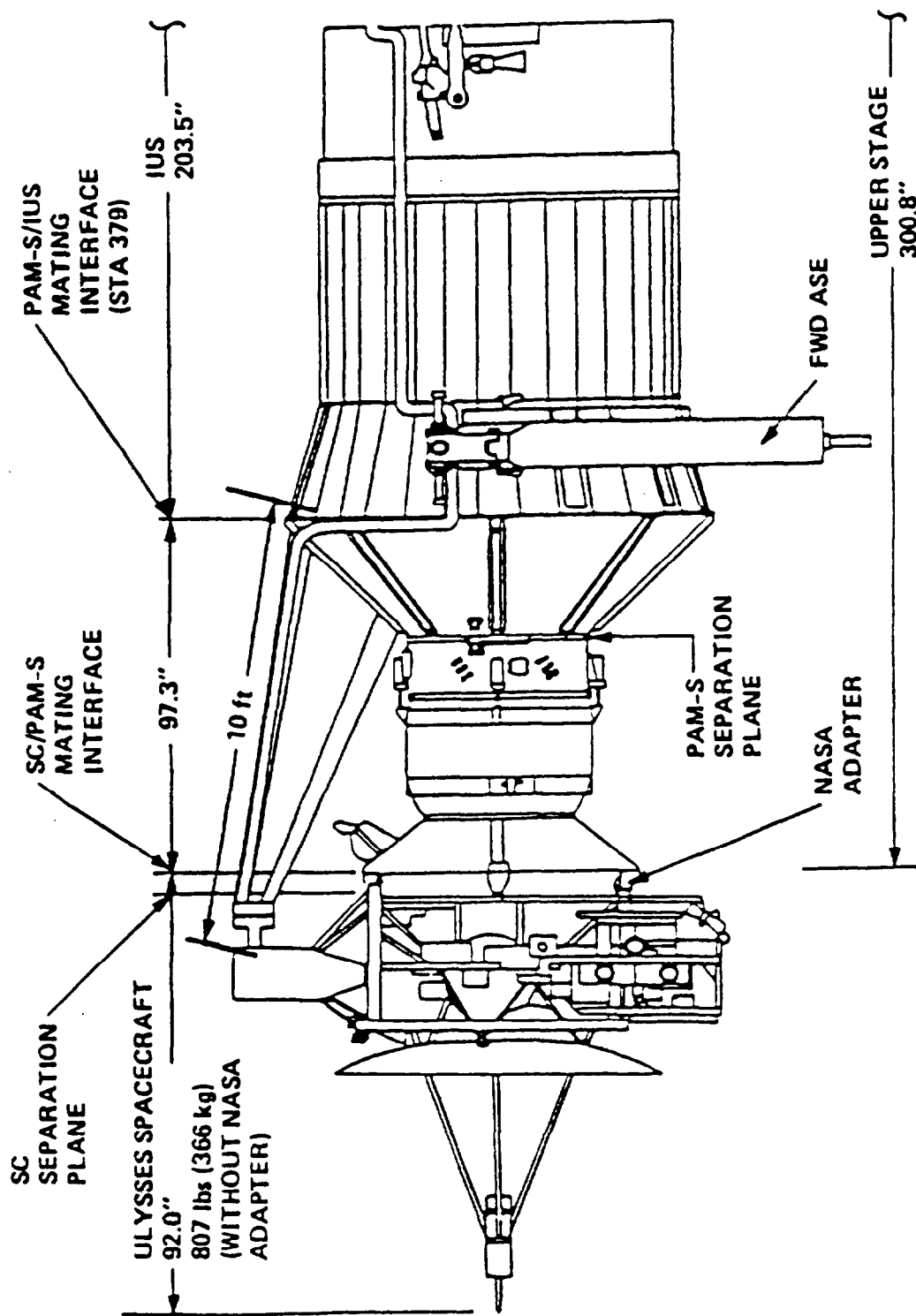
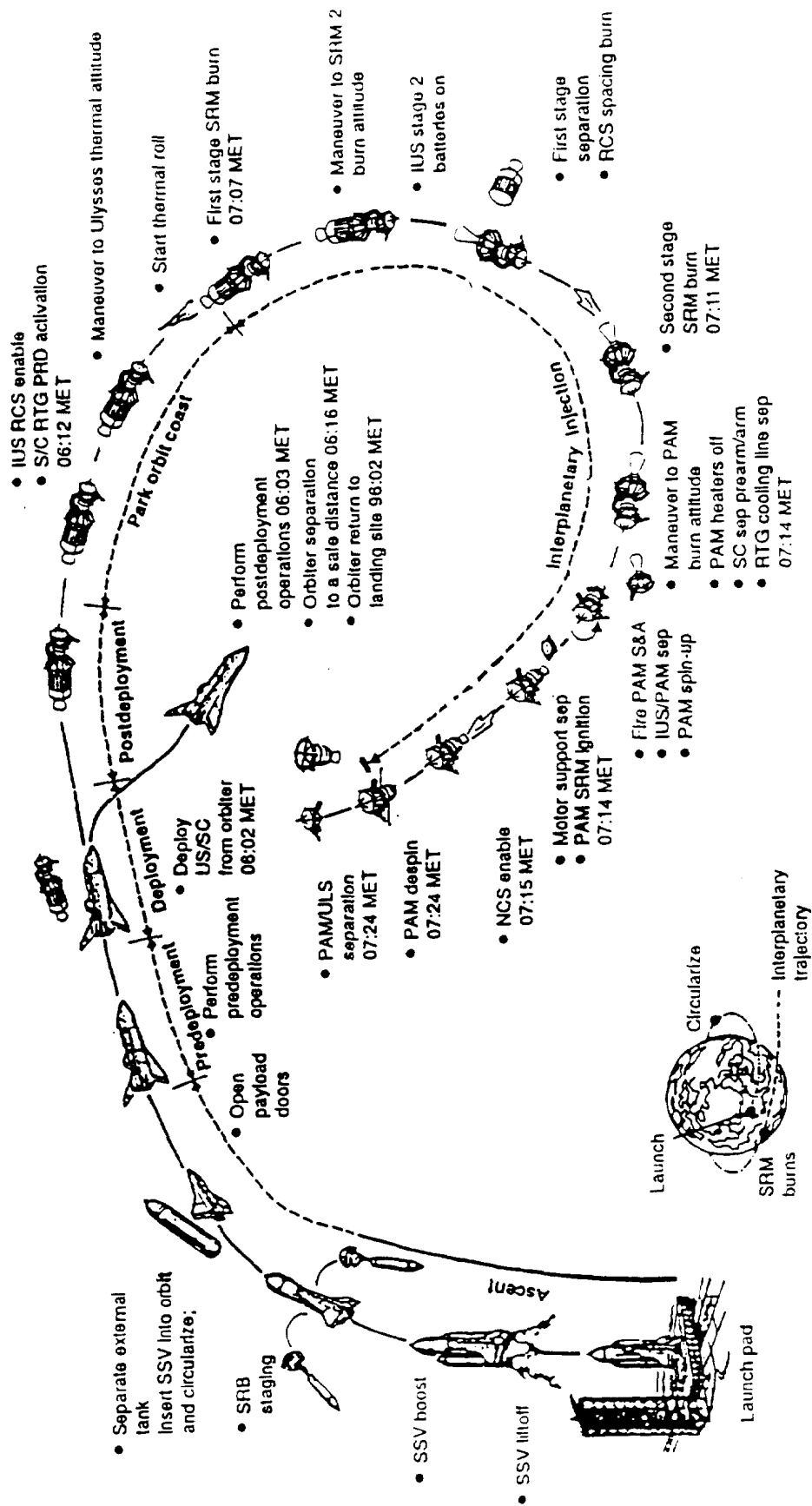


Figure 4. Ulysses/Upper Stage Payload Configuration



Mission Overview

Figure 5. Ulysses Launch Sequence

TABLE 2. ULYSSES RESPONSIBILITIES

NASA	ESA
<ul style="list-style-type: none"> • Project Management <ul style="list-style-type: none"> - Jointly with ESA - Governed by NASA/ESA MOU • Launch Vehicle • Radioisotope Thermoelectric Generator (RTG) • Tracking and Data Acquisition • Mission Design (Joint) • Mission Operations (Joint) • Navigation • Data Records • Science Investigations (Joint) • Parts Procurement (Support) • Integration and Support 	<ul style="list-style-type: none"> • Project Management • Spacecraft Development Test and Launch • Mission Design (Joint) • Mission Operations (Joint) • Science Investigations (Joint) • Operations Software Development

Mission Operations

Ulysses spacecraft flight operations are to be conducted at JPL under the responsibility of ESA's Director of Operations, located at the European Space Operations Center, Darmstadt, Germany. The Ulysses Flight Team (see Figure 6) is directed by the ESA Mission Operations Manager and JPL Deputy and is organized into spacecraft operations, led by the Spacecraft Operations Manager, and ground operations, led by the Ground System Manager.

Spacecraft operations are divided among the Spacecraft Control Team, the Control Processing Support Team, and the Flight Dynamics Team, all staffed by ESA. The Spacecraft Team is responsible for planning and implementing spacecraft operations, monitoring spacecraft health, and providing quick-look science data to the science investigators.

Ground system operations are divided among the Navigation Team, the Ground Operations Team, and the Data Management Team. These teams are responsible for navigation and maneuver planning support to flight dynamics, for real-time liaison with DSN tracking and MCCC Operations Controllers, and for preparation and delivery of science data records. The ground system operations task is staffed by JPL personnel.

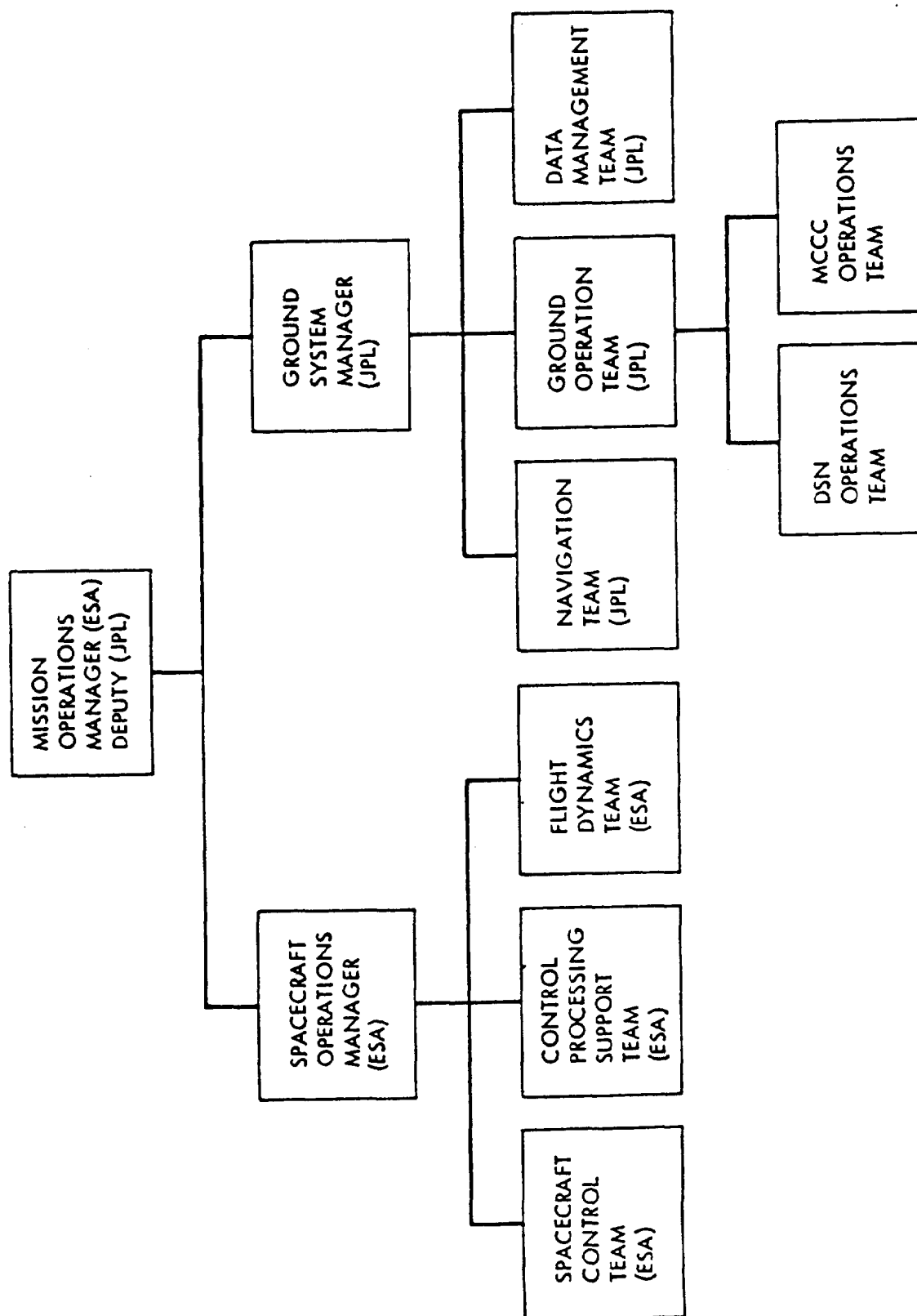


Figure 6. Ulysses Flight Team

Spacecraft telemetry data will be acquired by NASA's Deep Space Network (DSN) stations at Goldstone (California), Madrid (Spain), and Canberra (Australia). These data will be transmitted to JPL's Mission Control and Computing Center (MCCC). The spacecraft has been designed such that playback data can be interleaved with real-time data and transmitted back to Earth during daily contact periods. Data received at the MCCC are then processed by a project-unique Ulysses Mission Control System (UMCS) and sent to the Data Records System (DRS). Real-time telemetry data will be processed immediately to establish the health of the spacecraft and instruments. The UMCS will also provide information about the spacecraft's attitude (with respect to the Earth) and enable correction maneuvers to be generated to keep the Earth-pointing spacecraft antenna on line. The UMCS will also generate command files for changing science instrument configurations and scheduling report and playback times.

Spacecraft experiment data, together with spacecraft ephemeris information, will be generated by the Data Records System (DRS). These data will be supplied to the Principal Investigators of each scientific experiment in the form of Experiment Data Records (EDR's) and Supplemental Experiment Data Records (SEDR's). The EDR's are specific experiment-related data, while the SEDR contains position information not readily available from science and engineering telemetry such as solar system geometries and spacecraft orientations. In addition, a Common Data Record (CDR), which pools information from different experiments, will be prepared and distributed to the Investigators.

SPACECRAFT DESCRIPTION

Spacecraft Configuration

Other than its unique trajectory, there are a number of aspects of the mission that make Ulysses unusual. First, the prime science measurement phase starts 3½ years after launch, when the spacecraft climbs above 70 degrees heliographic latitude. This imposes a requirement for very high reliability in both spacecraft and payload design. Because the spacecraft will be exposed to a high dose of radiation during the Jupiter fly-by, all electronic components have been specially selected for their radiation resistance. Moreover, because Ulysses cannot rely on solar energy to provide electrical power, a Radioisotope Thermoelectric Generator (RTG) will be used to supply 280 Watts to power both spacecraft and instruments.

Ulysses will be spin-stabilized at a rate of approximately 5 rpm. Its high-gain antenna will be permanently pointed towards the Earth by precession maneuvers to adjust the attitude approximately every other day throughout the five-year mission. A "watchdog" system will ensure that the spacecraft points towards the Earth automatically, so that contact is not lost. The telemetry system will operate in the X-band at approximately 8 GHz, while a low-power 2 GHz S-band transmitter will also be available for radio science investigations and early orbit maneuvers. Uplink communication will be in S-band.

The spacecraft was designed and built by the STAR Consortium of European Industries with Dornier Systems of Friedrichshafen, West Germany as prime contractor to ESA (Figure 7).

Spacecraft mass properties and balance have been the prime drivers in the spacecraft design to meet the requirements both for the launch configuration and for the deployed boom configuration. The nominal mass of the spacecraft is 366 kg (807 lb) at launch, the on-board scientific instrumentation accounting for 55 kg (120 lb). The body-mounted experiments are located around the periphery on one side of the spacecraft to provide the required fields of view, good EMC shielding, and minimum radiation background from the Radioisotope Thermoelectric Generator located on the opposite side of the spacecraft. Several sensors are mounted on the radial boom, which is shown in Figure 7 in a near-stowed position.

The spacecraft will nominally be tracked 8 hours per day throughout the mission by the NASA Deep Space Network (DSN). Since continuous data coverage is of primary scientific importance, the spacecraft has two redundant tape recorders, each having 45.8 Megabit capacity. One recorder can therefore provide 24 hours of data storage at a rate of 512 bits per second. During periods of spacecraft tracking, 4096, 2048, or 1024 bits per second of real-time data will be transmitted, interleaved with playback of stored

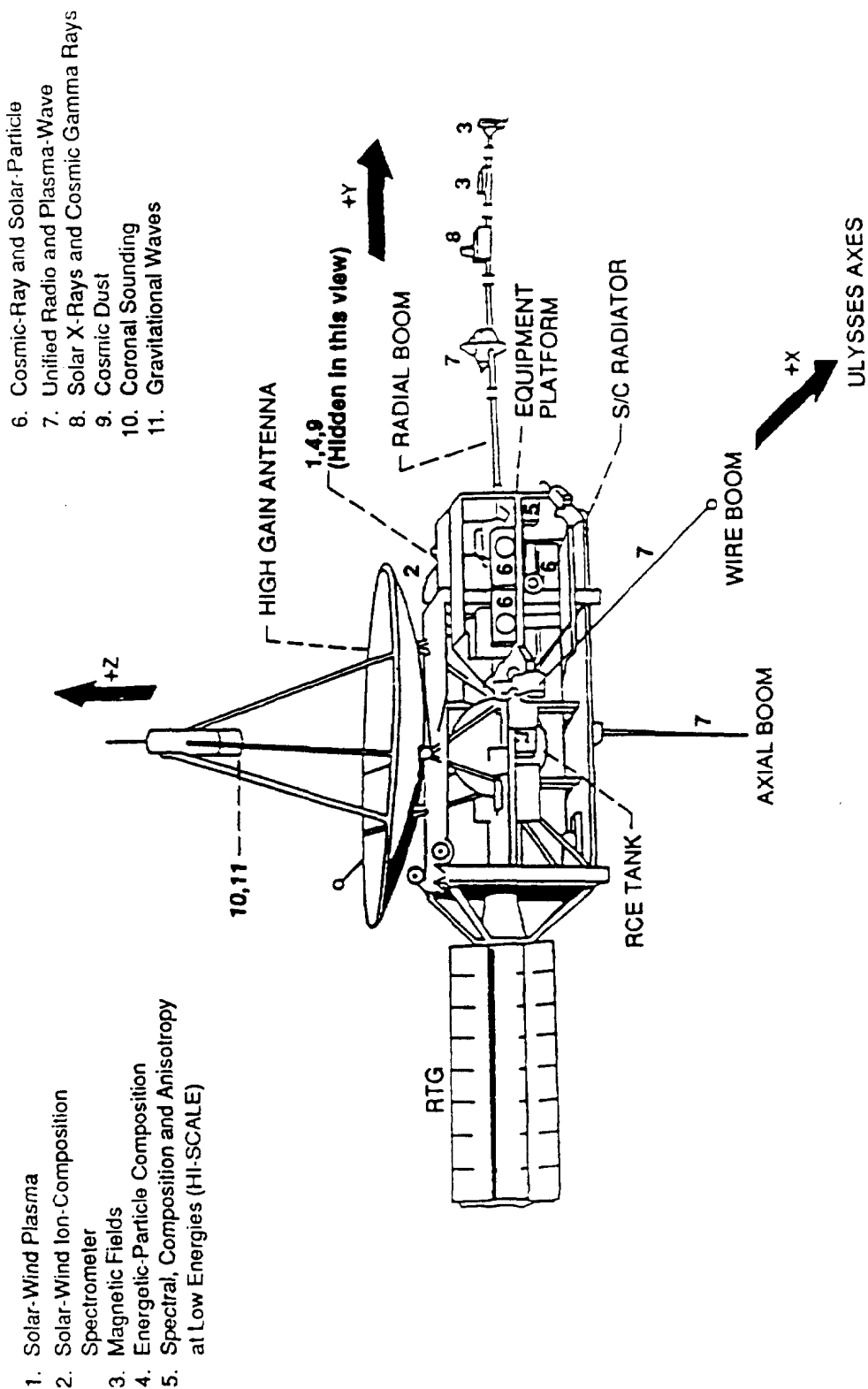


Figure 7. Ulysses Spacecraft Configuration

data. During storage periods data rates of 512, 256, or 128 bits per second can be selected.

Prominent characteristics of the spin-stabilized spacecraft are the large diameter (1.55-meter) parabolic high gain antenna (HGA) on top of the spacecraft, the Radioisotope Thermoelectric Generator (RTG), and the 5.5-meter radial boom, which provides an appropriate electromagnetically clean environment for certain experiments. A 72-meter tip-to-tip dipole wire boom and an 8-meter axial boom serve as electrical antennas for the unified radio and plasma-wave experiment. The body of the spacecraft contains engineering subsystems and science instruments with the exception of those experiment sensors mounted on the 5.5-meter boom. The internally mounted units are carried on a honeycomb centerpanel, which also supports the hydrazine fuel tank for the reaction control equipment of the Attitude and Orbit Control Subsystem. In general, the experiments that are more sensitive to nuclear radiation are mounted on the portion of the spacecraft farthest from the RTG, while the less sensitive subsystems are nearer to it.

Unique Design and Operational Features

Interplanetary missions require a spacecraft designed quite differently from satellites operating in Earth's orbit. At Jupiter, which is about 780 million km (485 million miles) from the Sun, the intensity of solar radiation is so weak ($1/25$ that of Earth) that photoelectric cells would never provide enough power. Furthermore, the solar cells would also deteriorate more rapidly because of the harsh radiation environment at Jupiter. Ulysses will therefore utilize a Radioisotope Thermoelectric Generator (RTG) to power all the scientific instruments and all the spacecraft subsystems, such as data handling.

Under an interagency agreement between the Department of Energy (DOE) and NASA, DOE developed and provided RTG power sources (Figures 8 and 9) for both the Galileo and the Ulysses spacecraft. Management coordination between DOE and NASA was the responsibility of JPL. The Galileo spacecraft, developed at JPL, utilizes an identical RTG.

After installation of the RTG on the spacecraft at the launch pad, the RTG is initially air-cooled to reduce the surface temperature in order to minimize thermal shock before water is introduced to the cooling tubes (the surface temperature is reduced to approximately 93 °C). Water for the cooling is subsequently supplied by an external portable cart while the spacecraft is on the launch pad; once the Shuttle bay doors are closed, cooling water is routed through the Shuttle heat exchanger. Prior to spacecraft deployment, the cooling lines are purged and vented with gaseous nitrogen.

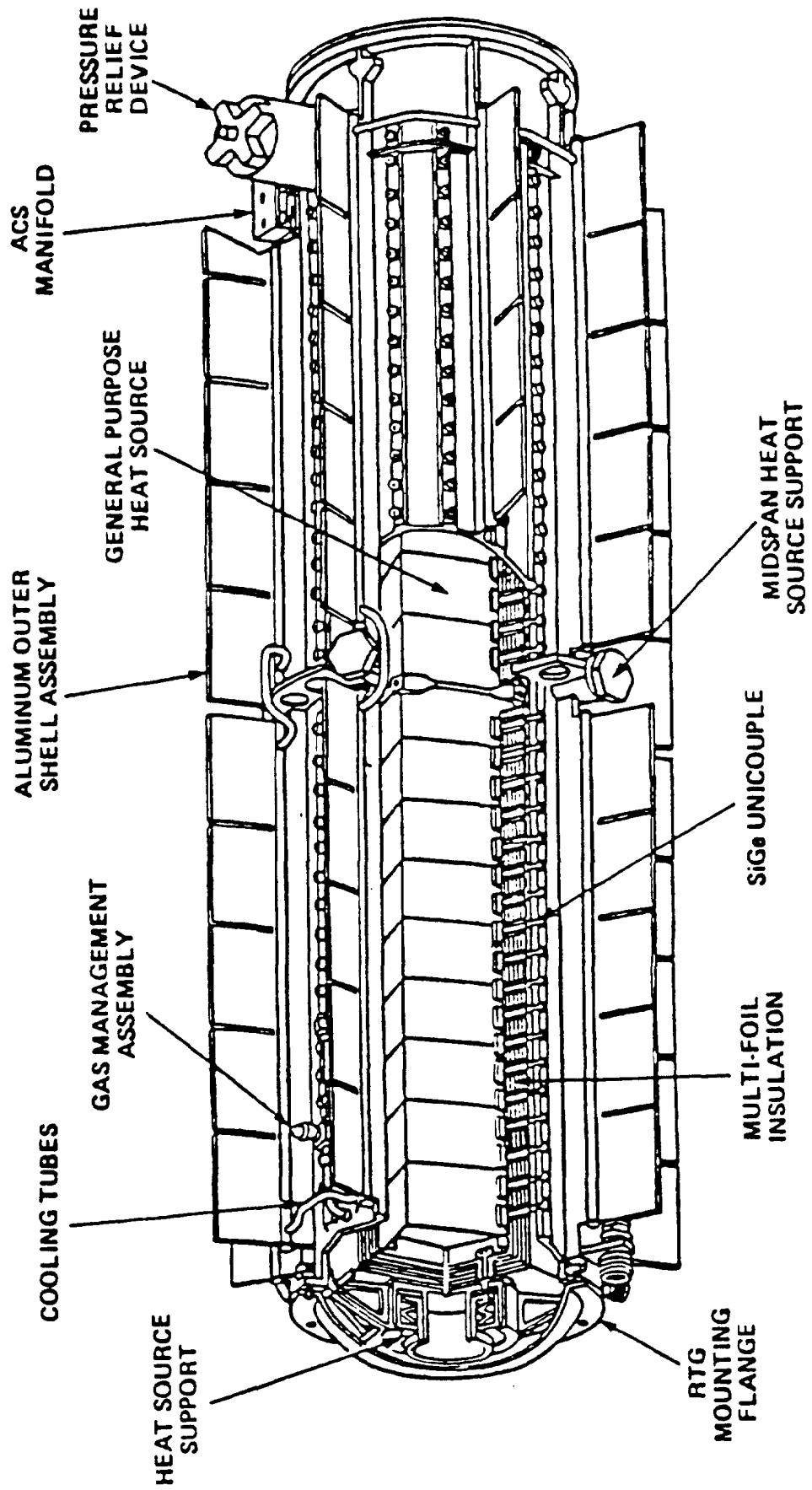


Figure 8. GPHS-RTG

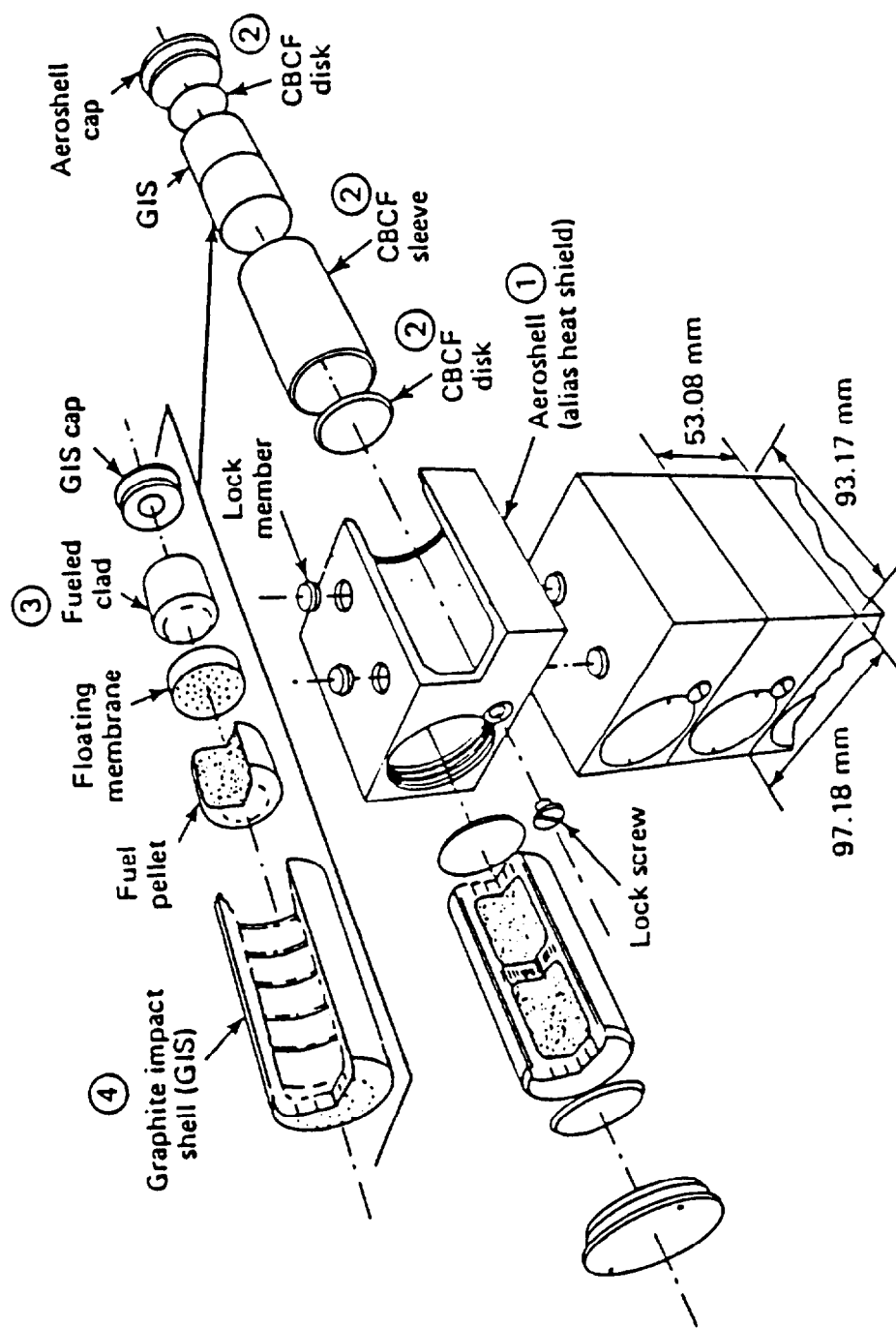


Figure 9. General Purpose Heat Source

Scientific Experiments and Instruments

The scientific payload on the Ulysses spacecraft consists of nine instruments. Scientists will use the spacecraft radio system to perform two additional experiments, bringing the total number of scientific investigations to eleven. Each investigation is headed by a Principal Investigator, supported by an international team of co-investigators having both flight-hardware and data-analysis responsibilities (Table 3).

TABLE 3. ULYSSES SCIENTIFIC EXPERIMENTS

Experiment	Principal Investigator	Experiment Code	Measurement	Instrumentation
Magnetic Field	A. Balogh, Imperial College, London	HED	Spatial and temporal variations of the heliosphere and Jovian magnetic field in the range 10.01 nT to 144000 nT.	Triaxial vector helium and fluxgate magnetometers.
Solar Wind Plasma	S.J. Bame, Los Alamos National Lab.	BAM	Solar-wind ions between 257 eV and 35 keV. Solar-wind electrons between 1 eV and 903 eV.	Two electrostatic analyzers with channel electron multipliers (CEMs).
Solar-Wind Ion Composition	G. Gloeckler, Univ. Maryland; J. Geiss, Univ. Bern	GLG	Elemental and ionic-charge composition, temperature and mean velocity of solar-wind ions for speeds from 145 km/s (H^+) to 1352 km/s (Fe^{14}).	Electrostatic analyzer with time-of-flight and energy measurement.
Low-Energy Ions and Electrons	L. Lanzerotti, Bell Laboratories	LAN	Energetic ions from 50 keV to 5 MeV. Electrons from 30 keV to 300 keV.	Two sensor heads with five solid-state detector telescopes.
Energetic-Particle Composition and Interstellar Gas	E. Keppler, Max-Planck-Institut, Lindau	KEP	Composition of energetic ions from 80 keV to 15 MeV per nucleon. Interstellar neutral helium.	Four solid-state detector telescopes. LiF-coated conversion plates with CEMs.

Experiment	Principal Investigator	Experiment Code	Measurement	Instrumentation
Cosmic Rays Solar Particles	J.A. Simpson, Univ. Chicago	SIM	Cosmic rays and energetic solar particles in the range 0.3-600 MeV per nucleon. Electrons in the range 4-2000 MeV.	Five solid-state detector telescopes. One double Cerenkov and semi-conductor telescope for electrons.
Unified Radio and Plasma Waves	R.G. Stone, NASA Goddard Space Flight Center	STO	Plasma waves: remote sensing of travelling solar radio bursts and electron density. Electric field: Plasma waves: 0-60 kHz; Radio receiver: 1-940 kHz Magnetic field: 10-500 Hz	72m radial dipole antenna, 7.5m axial monopole antenna. Two-axis search coil.
Solar X-Rays and Cosmic Gamma-Ray Bursts	K. Hurley, Univ. Calif.-Berkeley; M. Sommer, MPI, Garching	HUS	Solar-flare X-rays and cosmic gamma-ray bursts in the energy range 5-150 keV.	Two Si solid-state detectors. Two CsI scintillation crystals.
Cosmic Dust	E. Grün, MPI, Heidelberg	GRU	Direct measurement of particulate matter in mass range 10^{-7} - 10^{-16} g.	Multi-coincidence impact detector with channeltron.
Coronal Sounding	M. Bird, Univ. Bonn	SCE	Density, velocity, and turbulence spectra of solar coronal plasma.	Spacecraft-to-Earth dual ranging doppler data.
Gravitational Waves	B. Bertotti, Univ. Pavia	GWE	Search for gravitational waves.	Spacecraft two-way doppler data.

Magnetic Field Experiment

Because magnetic field lines are borne outward across space on the wings of the solar wind, knowledge of the shape and structure of the field lines at high latitudes is important to those who are studying the solar wind and the energetic charged particles. If the solar wind is simple above the poles, it should be possible to infer the character of the magnetic fields at the Sun's polar caps. Very little is known about the fields there

(such as their strength) because it is nearly impossible to observe them from the lower latitudes where all earlier spacecraft have flown.

A pair of magnetometers, each suited to a different purpose, is carried aboard Ulysses to map the heliospheric magnetic field as the spacecraft travels through it. Use of the pair of magnetometers will allow the investigators to monitor changes in the magnetic field at the spacecraft. A vector-helium magnetometer will measure slight fields, while near Jupiter a flux-gate magnetometer will measure the planet's intense magnetic field. Still more important, the two magnetometers will measure the magnetic fields above the Sun's poles.

The magnetometer team, interested in particle streams riding the solar wind outward from the Sun, seeks answers to questions such as whether the magnetic field lines near the poles cause clouds of plasma to act differently than they do nearer the equator. For example, the field lines at the poles are expected to arrange themselves nearly parallel to the flow of the solar wind, so the plasma clouds are not kept distinct and separate, as they are at the equator where the field lines are perpendicular to the flow.

Dr. Andre Balogh of Imperial College, London, is the principal investigator on the magnetometer experiment and has provided the flux-gate magnetometer. Dr. Edward J. Smith of Jet Propulsion Laboratory, the U.S. project scientist and a co-investigator on the magnetic-fields team, provided the vector-helium magnetometer.

Solar-Wind Plasma Experiment

Scientists know little about the speed, density, direction, and temperature of plasmas in the solar wind at high latitudes. If the solar wind at the poles originates from coronal holes there, it would be free of many of the complications associated with coronal holes near the equator. Near the equator, when quiet regions of the rotating corona pass a given location, low-energy particles stream forth. When the coronal holes move past the same site, high-speed particles pour out and overtake the slower low-energy particles. Thus, scientists who have measured the solar wind are perplexed by the alternating slow and fast streams. At the poles, however, effects associated with the collisions between slow and fast streams may be absent.

A solar-wind plasma experiment acts like a space version of a weather station and will measure the solar wind after it leaves the corona. The experiment will detect and analyze particles in the solar wind with the goal of determining variations in the particles from the equator to the poles. The plasma experiment will determine just how the solar wind changes as a function of distance from the Sun and distance from the ecliptic plane. The plasma instrument will measure local changes in the number of particles and in their energy as the solar wind blows past Ulysses while it travels along its flight path.

The plasma instrument should be able to measure how the properties of the solar wind differ between low and high latitudes and should be able to trace the solar wind back to its place of origin more easily at the poles than at the equator. The solar-wind plasma instrument will observe particles in the energy range from 1 electron volt to 35,000 electron volts.

Dr. Samuel J. Bame of the Los Alamos National Laboratory is principal investigator.

Solar-Wind Ion-Composition Experiment

Temperatures in the corona vary depending on the state of the magnetic fields in the photosphere beneath. High temperatures create mixtures of ions that are different at different heights. Each mixture is then locked into the solar wind; it does not change as it leaves the corona. The solar wind contains electrons, protons, alpha particles (the nuclei of helium atoms), and heavy ions such as oxygen, silicon, and iron. The relative amounts of all those materials are not well understood but are expected to vary with differing local conditions and changes in the corona where the materials formed. An important measure is their degree of ionization, a result of differing temperatures at the source.

A solar-wind ion-composition spectrometer is expected to provide unique information on conditions and processes in that region of the corona where the solar wind is accelerated. The instrument will study composition and temperatures of heavy ions in the solar wind as they strike the spacecraft. Once scientists have determined these temperatures, they should be able to find the location in the corona of the sources of the solar wind, the coronal heating processes, and the extent and causes of variations in composition of the Sun's atmosphere.

Dr. George Gloeckler of the University of Maryland and Dr. Johannes Geiss of the University of Bern, Switzerland are coprincipal investigators.

Low-Energy Ions and Electrons Experiment

An instrument called HI-SCALE (Heliospheric Instrument for Spectral, Composition and Anisotropy at Low Energies) will study low-energy interplanetary ions and electrons with a wide range of energies, from high-energy particles in the solar wind to particles with extremely high energies -- the Sun's equivalent of cosmic rays. Scientists hope to understand the mechanisms that release solar-flare particles and the dynamic phenomena that are associated with the solar cycle's maximum activity.

The instrument will use the flow of high-energy particles from eruptive processes on the Sun to study structural changes in the corona and in the magnetic field lines. (They can do that because the Sun's high-energy particles travel paths that reveal the field lines

carried by the solar wind.) The structures are expected to change as the spacecraft flies ever-further from the ecliptic plane. Interactions between the particles and waves that move through the solar wind also may be responsible for the energy imparted to particles in the solar wind and therefore could explain their speeds.

Scientists on the HI-SCALE team will also try to measure the composition of low-energy nuclei from the Sun both in the ecliptic plane and at high solar latitudes, as these nuclei should give information on the Sun's composition. The instrument should also provide clues about how the masses of individual particles influence their acceleration due to electromagnetic forces.

Dr. Louis Lanzerotti of Bell Laboratories is principal investigator.

Energetic-Particle-Composition and Interstellar Gas Experiment

While the high temperatures in the Sun's corona accelerate the solar wind's low-energy particles, the medium- and higher-energy particles achieve energies that are much too great to have been caused by such relatively simple heating processes. No one knows what processes cause the acceleration of the medium- and high-energy particles. In addition, once the particles with medium and high energy are accelerated, they appear to be stored temporarily in the corona, to be released sometime later along the magnetic field lines. (Physicists observe solar flares where the particles originate, but they do not see any of the particles arrive at Earth at the time they should.) The structures in the corona where the storage and acceleration processes are believed to occur are apt to extend to high solar latitudes during the period of maximum solar activity -- just as Ulysses is flying over the Sun's poles.

The energetic-particle instrument will detect the particles of medium energy in an effort to understand the processes of the coronal-storage phenomenon and how that storage depends on the particles' energy. The instrument will also study how solar latitude affects the paths along which the particles move through the heliosphere.

The other experiment that is allied with the energetic-particle detector will search for neutral helium -- atoms that have no net electric charge -- coming from the Milky Way. Interstellar hydrogen and helium gas exists throughout the Milky Way, perhaps as both a remnant and a source of the star-formation process. The solar system moves through that gas as we orbit the center of the galaxy.

Neutral helium is extremely difficult to detect. However, hydrogen is even more difficult to see in the inner heliosphere, as a helium atom is four times more massive and holds on to its electrons with a stronger force. Since it has no electric charge to trap it in the Sun's magnetic field lines, the helium falls directly in toward the Sun, drawn there by gravity. The helium atoms therefore penetrate deeper into the solar system (to about

the Earth's distance) than the hydrogen atoms before they are ionized and carried outward again by the solar wind.

The interstellar helium can't be detected until the Sun's gravity gives it enough speed, which doesn't occur until the helium is between 1.2 and 1 astronomical units from the Sun. Therefore, the helium-detection portion of the experiment will operate only during the first 70 to 100 days of the flight.

Dr. Erhardt Keppler of the Max-Planck-Institut für Aeronomie in West Germany is principal investigator of the energetic-particle detection experiment. Dr. Helmut Rosenbauer, also of the Max-Planck-Institut für Aeronomie, is principal investigator of the interstellar neutral helium experiment.

Cosmic-Ray and Solar-Particle Experiment

A cosmic-ray and solar-particle investigation will search for particles inbound from other regions in the Milky Way galaxy. Team members hope to sample these objects in near-pristine condition, unaltered by the Sun's magnetic field lines near the ecliptic plane. The experiment's goal is to improve our understanding of acceleration and movement of charged particles in interplanetary space -- primarily the cosmic rays that originate beyond the solar system. It will address questions regarding the nature of cosmic rays before they enter the solar system, how galactic cosmic rays change, and, from measurements of particles not accessible in the plane of the ecliptic, how and where cosmic rays originate, what forces act on them, and how they travel through the Milky Way.

The experiment can distinguish between the different elements present in cosmic rays. It can identify such heavy particles as hydrogen nuclei, helium nuclei, oxygen, and nitrogen. The physicists on this team also hope to determine individual isotopes of each element, which would tell them about how the cosmic rays were created.

Dr. John Simpson of the University of Chicago's Enrico Fermi Institute is principal investigator.

Unified Radio and Plasma-Wave Experiment

The Sun is a mighty broadcaster of radio signals that move across the solar system at the speed of light, and high-energy electrons that move outward as the result of solar eruptions also produce low-frequency waves of energy.

Ulysses' unified radio and plasma-wave experiment has two objectives: the first is to determine the direction and polarization of radio sources flowing outward from the Sun; the second is a detailed study of waves in the solar wind -- waves associated with local variations in the properties of clouds of plasma that move through the interplanetary

medium. The unified radio and plasma-wave experiment is both a remote-sensing and a local-measurement instrument. It senses the longer radio frequencies that originate at great distances and the shorter plasma-wave frequencies as they move past the spacecraft.

Scientists on this team, along with colleagues on other teams, are seeking to understand the basic physics of plasmas -- clouds of particles that have lost one or more of their electrons and thus have been electrically charged. Electrons that move with the plasma cloud follow magnetic field lines of the heliosphere, emitting electromagnetic waves. Both ions and electrons in streams of plasma interact with the solar wind to create plasma waves. Scientists especially want to understand three characteristics of the waves: their source, how they interact with the solar wind, and how various kinds of waves depend on the medium through which they move.

Dr. R. G. Stone of NASA's Goddard Space Flight Center is principal investigator.

Solar X-rays and Cosmic Gamma-Ray Bursts Experiment

In 1959 scientists discovered that solar flares emit X-rays; in 1973 they discovered gamma rays bursting into the solar system intermittently from interstellar space; and in 1983 X-rays emitting from Jupiter were discovered. Little is known about any of these phenomena, and least is known about gamma rays; they do not originate from the Sun but from elsewhere in the galaxy. Scientists have encountered problems explaining the perplexing gamma-ray observations. How are the gamma rays produced? What objects are responsible for the extremely high-energy gamma rays? Supernovas? Black holes? The physicists have not yet been able to triangulate gamma-ray bursts closely enough to pinpoint their sources.

The solar X-rays and cosmic gamma-ray bursts experiment is intended to provide new data on these perplexing high-energy particles. The solar-flare X-ray portion of the experiment will work in conjunction with spacecraft flying in the ecliptic. The goal is to determine how the intensity of the bursts varies with their direction.

Observations of X-rays from the Sun by Ulysses and those by spacecraft in the ecliptic, such as Galileo, which will be en route to Jupiter, will help to determine the movement of electrons within intense solar-flare magnetic fields on the Sun. The physicists of Ulysses also want to measure how the energy of the solar X-rays differs as the flares emit them in different directions.

Gamma-ray bursts are fairly rare events compared with other phenomena that Ulysses will study, but during its mission Ulysses is expected to sense more than 50 per year as they pass through the solar system.

Dr. Kevin Hurley of the Centre d'Etude Spatiale des Rayonnements, France, and Dr. Michael Sommer of the Max-Planck-Institut für Extraterrestrische Physik, West Germany, are coprincipal investigators.

Cosmic Dust Experiment

Cosmic dust probably originated in several different ways. Some may be left over from the creation of the solar system. Some has undoubtedly been left behind by comets streaking past the Sun. Still other dust may have come from collisions of great boulders in the asteroid belt. Finally, some cosmic dust probably enters into the solar system from interstellar space.

Dust particles in space are extremely tiny, about the size of the particles in cigarette smoke. Two basic forces act on the dust particles at the same time: gravity and solar radiation. Depending on their size, individual particles can be drawn inward toward the Sun by gravity or forced outward by the pressure of solar radiation. Still other dust particles are just passing through, on their way from interstellar space through the solar system and out again.

The Ulysses dust experiment aims to measure the speed and flight direction of particles. It will measure the electric charges the particles acquire as they fly through the solar wind, and it will attempt to determine if the dust exists in greater amounts at higher latitudes than in the ecliptic plane.

Dr. Eberhard Grün of the Max-Planck-Institut für Kernphysik in West Germany is the principal investigator.

Coronal Sounding Experiment

Twice during the Ulysses mission the spacecraft and the Earth will be on opposite sides of the Sun. The first such orientation will occur about 10 months after launch; the second about one year later. During these opportunities scientists will use radio signals to and from Ulysses to measure the density of electrons along the path the radio signals take from Earth to the spacecraft and back as they pass the Sun.

Because interplanetary space is not a perfect vacuum, the radio signals' speed will be slightly affected by the material they pass through. Therefore the frequency of the signals will change slightly as they pass through the Sun's corona. Part of that shift is caused by relative motions of the spacecraft and Earth. Yet another part is caused by the electrons in the signals' path. In addition, irregularities in electron density make the radio waves scintillate or "twinkle" just as starlight does, and that scintillation is a measure of the number of electrons near the corona. What is unique about the

measurements of Ulysses' radio signals is that they will count the electrons streaming from a region of the Sun that has never been seen before -- high solar latitudes.

Dr. Hans Volland of Bonn University is the principal investigator.

Gravitational Waves Experiment

Ulysses may provide evidence in support of Albert Einstein's theory of gravitation (the Theory of General Relativity). Relativity predicts the presence of gravitational waves, which are ripples in Einstein's space-time caused by matter or mass in motion.

Particularly strong waves could be produced by cataclysmic events involving vast amounts of matter in quasars and the centers of exploding galaxies. An example of such an event would be the collapse into a black hole of matter equivalent to 100 million times the Sun's mass. Current astronomical observations appear to lend credence to the existence of such objects in the centers of galaxies. Gravitational waves would travel out from such events through space at the speed of light and disturb the position of any object they pass.

MISSION SEQUENCES

The major mission events are depicted in Table 4. In the first leg of the mission, the spacecraft will travel nearly in the plane of the ecliptic to Jupiter. The Jovian gravitational field, precisely targeted, will be used to deflect the spacecraft out of the ecliptic plane. After Jupiter swingby, which will occur about February 1992, the spacecraft will travel in a heliocentric, out-of-ecliptic orbit with a high heliographic inclination. It will pass over the poles of the Sun and will spend a total of at least 150 days at 70 degrees above the ecliptic. At maximum heliocentric or solar latitude, the distance from the Sun will be less than 2.3 AU. The subsequent pole-to-pole segment of the trajectory will be traversed relatively quickly, and the second (northern) polar passage will occur approximately 12 months after the first.

TABLE 4. MAJOR MISSION EVENTS

Launch Period	October 5-23, 1990
Jupiter Flyby	February 1992
First Polar Pass (above 70° S Solar Latitude)	May-September 1994
Second Polar Pass (above 70° N Solar Latitude)	May-September 1995
End of Baseline Mission	September 1995
End of Baseline Project	March 1996

Launch

The Ulysses mission will be launched aboard the Space Shuttle Discovery from Launch Complex 39B, Kennedy Space Center, with a flight azimuth of 90 degrees and a nominal circular park orbit at an altitude of 160 nm. Inclination resulting from the launch azimuth and boost flight path will be approximately 28.5 degrees. Launch windows are outlined in Table 5.

Mission Events

After launch, Ulysses will be one of the fastest man-made objects in the universe with an escape velocity of 11.4 km per second. When Ulysses is furthest from the Earth it will be 950 million km from our planet, and it will take almost an hour for the signals to travel from Ulysses to Earth, or for commands to reach the spacecraft.

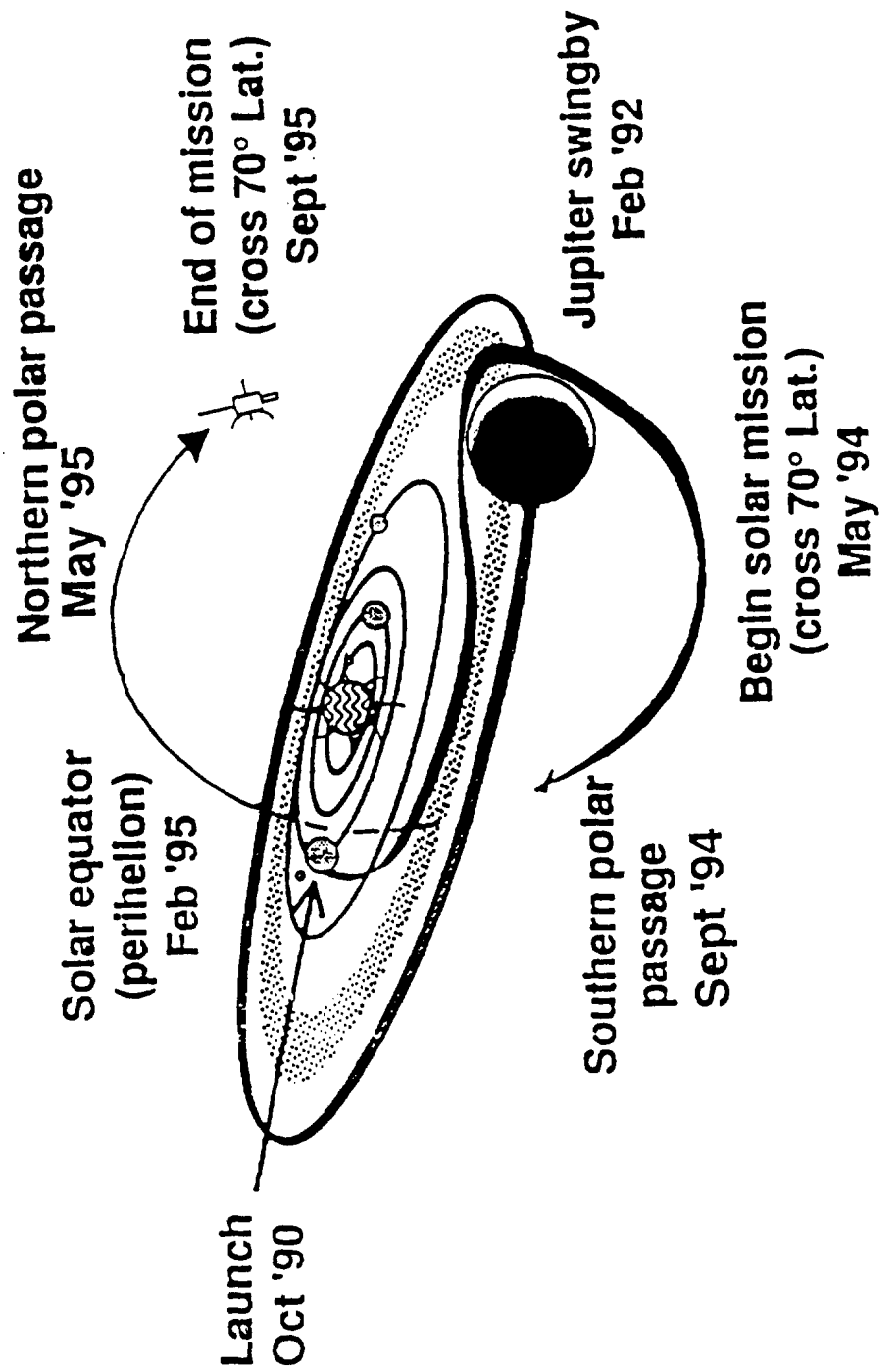
TABLE 5. ULYSSES LAUNCH WINDOWS

Launch Date 1990	Window Open (GMT)	Window Close (GMT)	Window Duration
	HH:MM	HH:MM	HH:MM
October 5	11:35	13:53	2:18
October 6	11:36	14:10	2:34
October 7	11:37	13:21	1:44
October 8	11:38	13:36	1:58
October 9	11:39	13:38	1:59
October 10	11:40	13:33	1:53
October 11	11:40	13:39	1:59
October 12	11:41	13:45	2:04
October 13	11:42	13:49	2:07
October 14	11:43	13:57	2:14
October 15	11:44	13:55	2:11
October 16	11:45	13:53	2:08
October 17	11:45	13:38	1:53
October 18	11:46	13:34	1:48
October 19	11:47	13:34	1:47
October 20	11:48	13:31	1:43
October 21	11:49	13:11	1:22
October 22	11:50	12:18	0:28
October 23	11:50	11:57	0:07

The opening of the launch window is based on providing a lighted landing at Edwards at nominal end of mission on orbit 66. The closing of the window is based on IUS performance requirements to support the Ulysses target.

An inertial Upper Stage/Payload Assist Module combination will place the spacecraft on an ecliptic transfer orbit to Jupiter (Figure 10). On its outward journey, Ulysses will perform interplanetary physics investigations and will search for gravitational waves during two periods when the Earth is directly between the spacecraft and the Sun. Upon arrival at Jupiter, approximately 16 months after launch, Ulysses will measure the Jovian magnetosphere. Ulysses will then use the massive Jovian gravitational field to deflect the spacecraft trajectory out of the ecliptic into a highly elliptical orbit toward the Sun's south pole, reaching previously uncharted heliographic latitudes. The most intense scientific activity will commence with the first polar pass, about three and a half years after launch. As the spacecraft passes through 70 degrees south solar latitude at twice Earth's distance from the Sun, Ulysses will "see" the Sun for the first time from all latitudes, including the poles. Ulysses will also study energetic charged particles originating in explosive releases of energy from the Sun, such as solar flares.

In response to the Sun's gravitational pull, Ulysses will arc toward the solar equator and cross it at about 1.2 AU. Although scientific investigations will continue throughout this period, interest will peak again when the spacecraft reaches high northern heliographic latitudes, approximately a year after crossing the Southern Pole. About five years after launch, Ulysses will have explored the heliosphere at nearly all latitudes, measured phenomena over both of the Sun's poles, and investigated interplanetary particles and fields. As the spacecraft leaves the region of the Sun's north pole, the mission will end.



Mission Objective: To conduct solar observations from high solar latitudes (greater than 70 degrees)

Figure 10. Ulysses Mission Profile

MISSION SUPPORT

Mission Control and Computing Center

Mission operations will be conducted from the Ulysses Flight Operations Center, located at the Jet Propulsion Laboratory.

Deep Space Network

The spacecraft will be tracked for 8 hours per day throughout the mission by the 34-m dishes of the NASA Deep Space Network. Spacecraft telemetry data will be acquired by DSN stations at Goldstone (California), Madrid (Spain), and Canberra (Australia). During periods when the spacecraft is being tracked, real-time data, interleaved with stored data, will be transmitted back to Earth. The data received will be transmitted to the Mission Control and Computing Center at JPL.

LAUNCH APPROVAL FOR NUCLEAR POWER SOURCES

Launch Approval Process

The launch approval process for the Ulysses mission is defined by a Presidential Directive, PD/NSC-25, dated December 14, 1977, that requires the President's Office of Science and Technology Policy (OSTP) to approve the launch of any nuclear power source. The process has been in place for all NASA missions requiring nuclear power sources since the 1970's and involves approximately 100 individuals from Federal agencies, private industry, universities, and the Executive Office of the President (Figure 11). An essential element of the safety review process is the Interagency Nuclear Safety Review Panel (INSRP) that provides an independent safety evaluation to the Office of Science and Technology Policy to support their deliberations prior to making a decision whether to approve the launch of any mission carrying nuclear materials. The panel consists of agency coordinators from the Department of Defense, the Department of Energy, NASA, and observers from the Nuclear Regulatory Commission (NRC), as well as technical specialists from the Environmental Protection Agency (EPA), and the National Oceanic and Atmospheric Administration (NOAA). There are six subpanels, with dozens of members from federal agencies, industry, and universities who review safety analysis reports developed by the DOE.

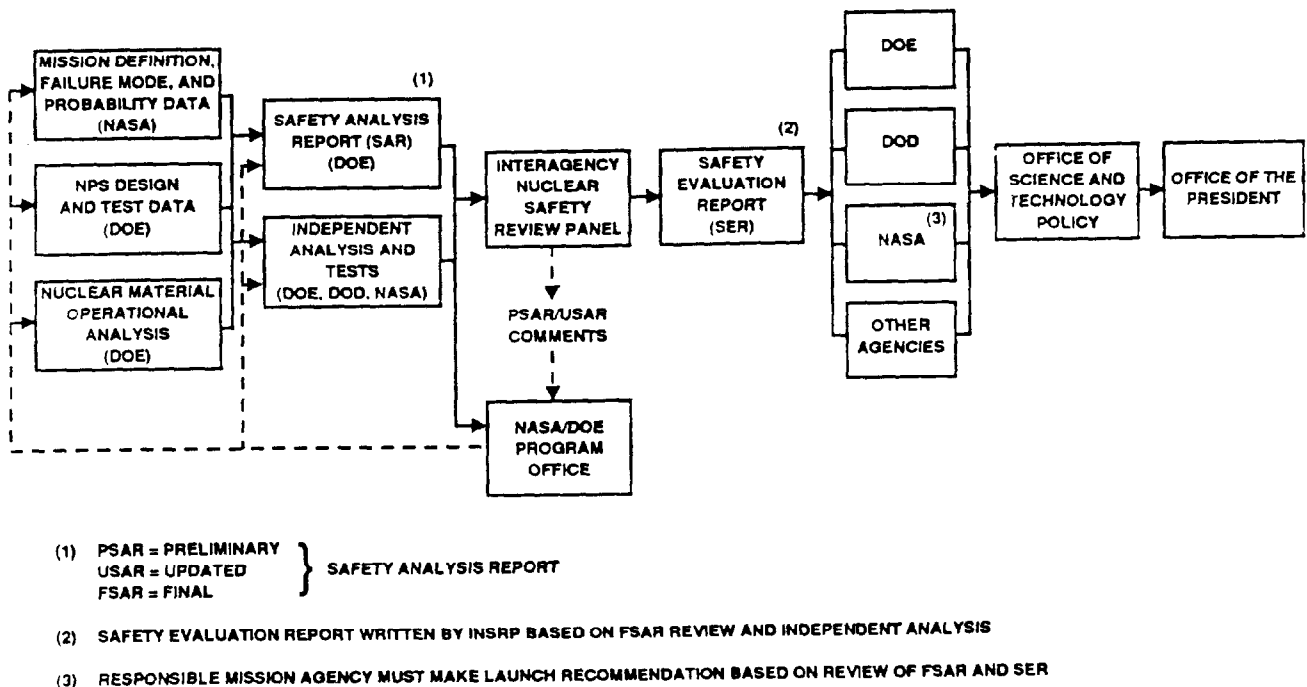


Figure 11. Aerospace Nuclear Safety Review Process

Nuclear Safety Analysis

Three safety analysis reports are developed during the course of a space nuclear power project such as Ulysses. The Safety Analysis Report is prepared by the Department of Energy (DOE). It includes a description of the mission and the nuclear power source, a failure modes analysis, radiological risk assessment, and summaries of test data.

The report also provides a description of the final design of the mission and its nuclear power sources, radiological safety data including the results of the safety tests, and a risk assessment of mission accidents including estimated human and environmental exposures to nuclear materials. Draft copies of the Safety Analysis Report are delivered to INSRP for examination by the subpanels, and comments are incorporated into the final version. The Ulysses FSAR was completed in March 1990.

The INSRP prepares a Safety Evaluation Report (SER) that assesses and summarizes the FSAR. When the evaluation is completed, the report is presented to the INSRP coordinators for final review. After the SER is published, it is distributed to NASA, DOE, and DOD for review. Once the DOE and DOD coordinators have reviewed the report's contents and analyses, the DOE and DOD agency heads decide whether to concur with or recommend against NASA's request for launch. If both DOE and DOD concur with NASA's request, NASA then proceeds to request launch approval from the President's Office of Science and Technology Policy. The OSTP Director can either approve the launch request or refer it to the President. No launch can take place without prior approval from either the OSTP Director or the President.

In addition to the documents mentioned above, NASA prepares an Environmental Impact Statement (EIS) as required by National Environmental Protection Agency regulations. The EIS presents an overview of the Ulysses mission, its scientific purpose, and the need for taking an action (launch of the Ulysses spacecraft) for which environmental consequences must be considered. The document discusses alternatives to NASA's planned course of action and then describes the potential environmental consequences. The Draft EIS was released for public comment in February 1990. Responses to the comments received were incorporated into the Final Environmental Impact Statement (FEIS), which was issued in June 1990. After public comments to the FEIS were received and considered, the final decision to proceed with the planned course of action was made by the Associate Administrator, Office of Space Science and Applications, and signed in August 1990. The decision is documented in the Ulysses Record of Decision.

MISSION MANAGEMENT

The Ulysses Mission is a joint activity of the National Aeronautics and Space Administration (NASA) and the European Space Agency (ESA) (Figures 12 and 13). The NASA portion of the project is managed under the Flight Programs Branch of the Solar System Exploration Division. NASA project management is assigned to the Jet Propulsion Laboratory (JPL) at Pasadena, California. The ESA portion of the mission is managed under the Directorate of Scientific Programmes, ESA Headquarters, Paris, France. ESA project management resides at the European Space Research and Technology Center (ESTEC) located in Noordwijk, The Netherlands. Flight operations for the ULS Mission are conducted under the responsibility of ESA's Director of Operations located at the European Space Operations Center, Darmstadt, Germany.

The NASA portion of the project is directed by the Office of Space Science and Applications (OSSA) at NASA Headquarters. Project management has been assigned by NASA to the Jet Propulsion Laboratory (JPL) in Pasadena, California.

Under the terms of the MOU between ESA and NASA, each agency designated a project manager.

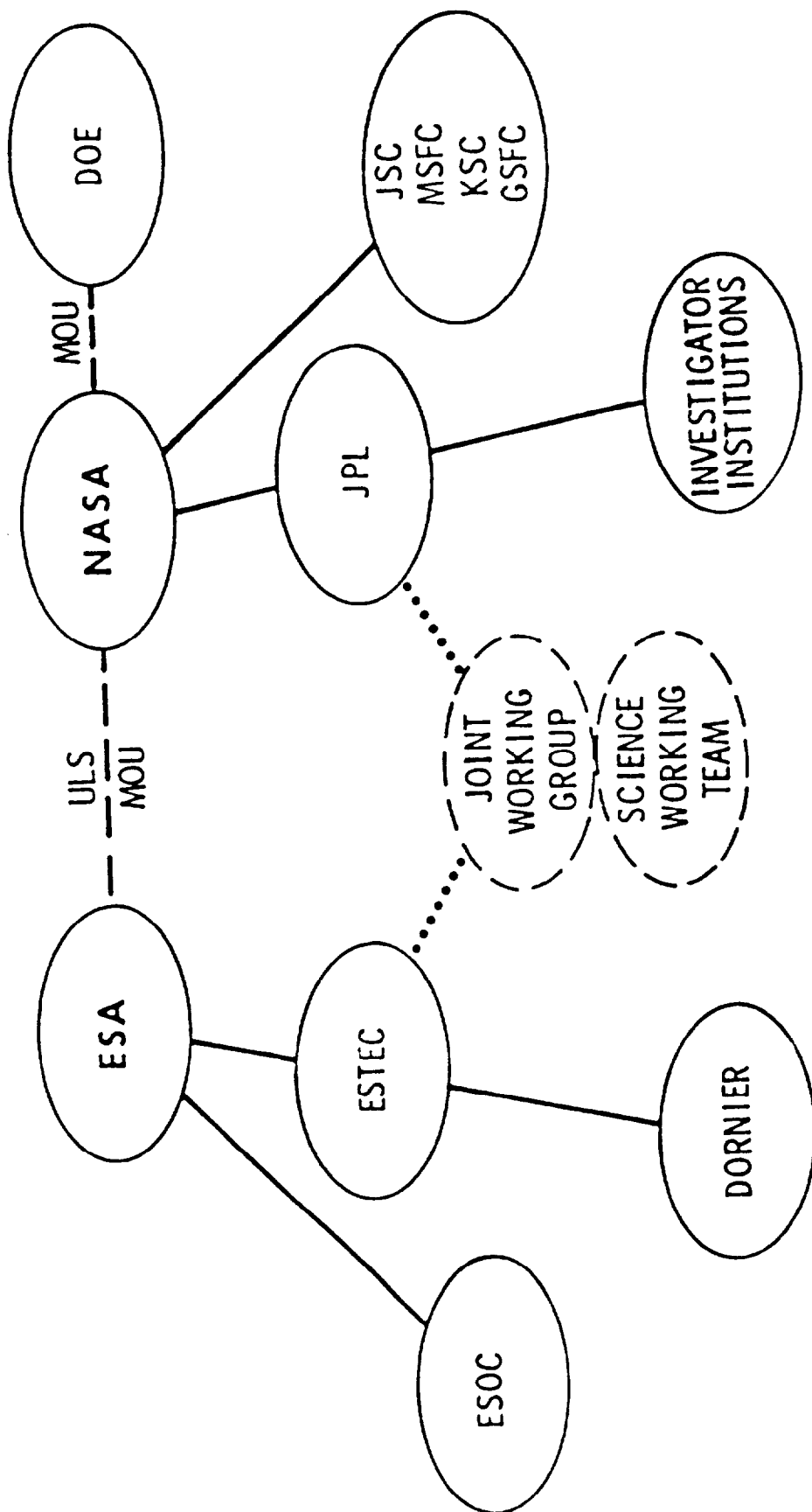


Figure 12. Ulysses Management Organization

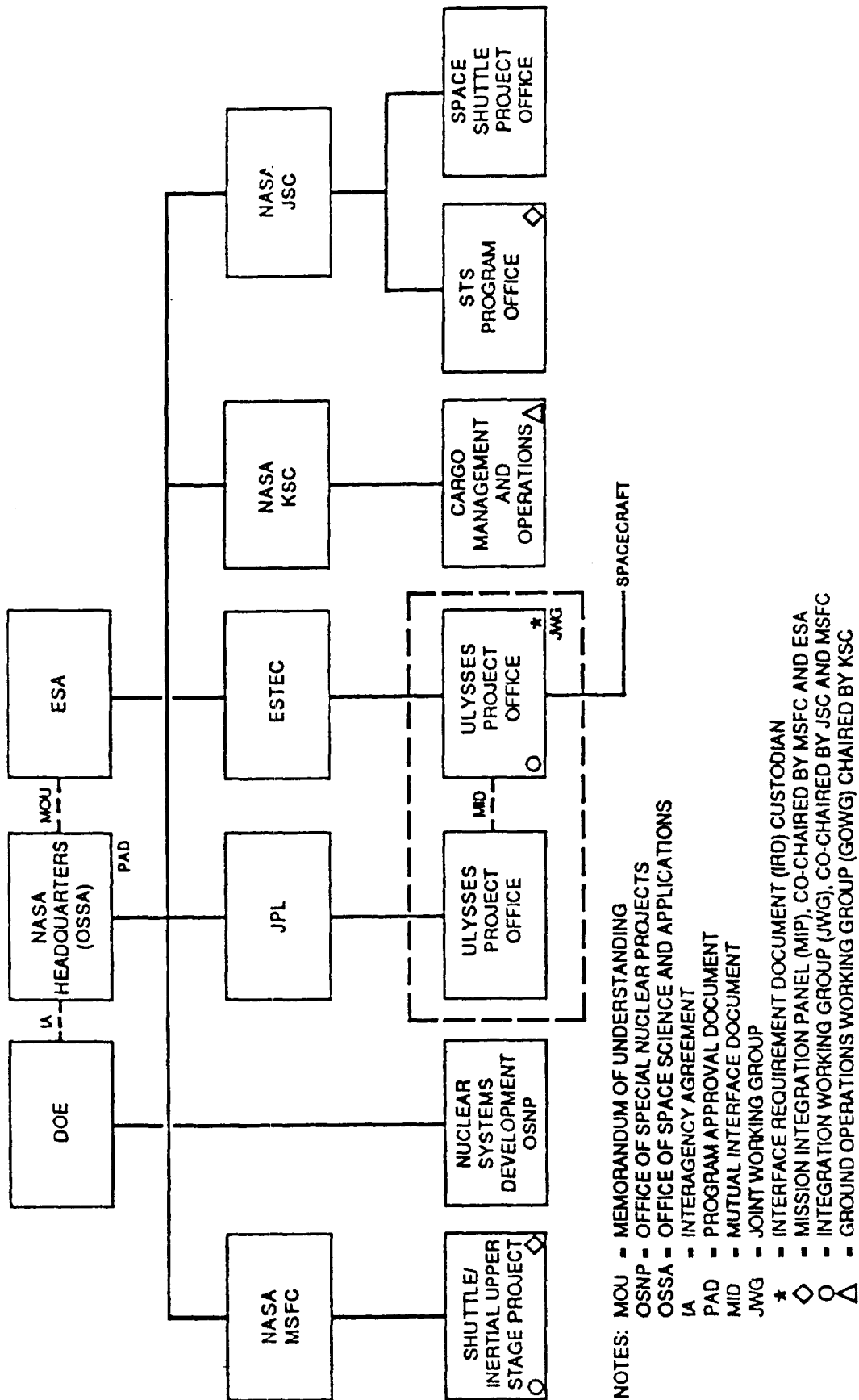


Figure 13. Ulysses Project Organization

PROGRAM COSTS

Total costs for the U.S. share of the Ulysses Program, excluding launch of the space shuttle and DSN operations, are indicated in Table 6. STS and DSN costs are budgeted separately. The data is presented in millions of real (or current year) dollars.

TABLE 6. ULYSSES PROGRAM COSTS

	Prior Years	Fiscal Year							Total
		1990	1991	1992	1993	1994	1995	1996	
Development	151.6	14.3	3.3						169.2
Mission Operations and Data Analysis			8.9	8.0	7.8	8.4	8.4	.7	42.2
Project Total	151.6	14.3	12.2	8.0	7.8	8.4	8.4	.7	211.4